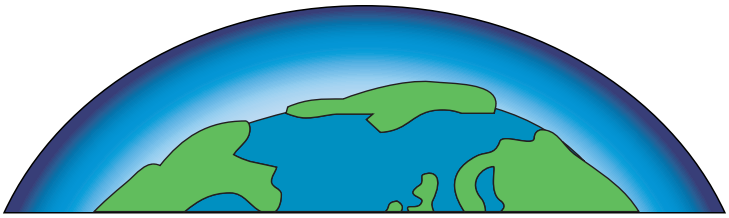


Lesson 9:
Atmospheric Science Mission

Students use an online, multimedia module to simulate the techniques that scientists might use to find a planet that has the atmospheric conditions required for human habitability. They learn about NASA research and careers in atmospheric sciences.

Main Lesson Concept: Scientists use methods (such as spectroscopy) and instruments (such as a spectrograph, thermometer, and barometer) to collect data from a planet. Scientists then interpret this data to help answer a scientific question, such as whether the planet has the necessary atmospheric conditions to support human habitability.

Scientific Question: How do scientists go about investigating whether a planet has the necessary atmospheric conditions for human habitability?

Objectives	Standards
• Students make predictions as to whether the atmospheres on Mars and Venus can support human habitability. • Students make observations, compare data, and reach conclusions regarding the atmospheric pressure, temperature, and composition on Mars and Venus. • Students identify the types of instruments that scientists use to gather data on the atmosphere of other planets. • Students identify the type of data scientists gather with these instruments.	***Addresses:*** 2061: 1B (6-8) #1, 2 NSES: A (5-8) #1, 2 ISTE: (5-8) #3, 5, 6

Assessment	Abstract of Lesson
Write-up in Astro Journal and responses to Astro Journal final questions.	Students predict whether the atmospheric conditions on Mars and Venus support human habitability. They engage in an online Atmospheric Science Mission module in which they simulate the methods scientists might use to determine whether Mars and Venus have the necessary atmospheric compositions, temperatures, and pressures to support human habitability. They share their results with the class and describe the process they used.

Prerequisite Concepts	Major Concepts
• Scientists do not pay much attention to claims about how something they know about works unless the claims are backed up with evidence that can be confirmed and with a logical argument. (2061: 1B (3-5) #4) • Humans need water, oxygen, food, gravity, a moderate temperature and protection from poisonous gases and high levels of radiation to survive. (Astronomy Lesson 1) • The atmosphere of a planet affects the planetary temperature system, which determines the temperature of that planet. (Astronomy Lesson 10) • Humans need oxygen, carbon dioxide, nitrogen, ozone, and water vapor in certain quantities. (Atmosphere Lesson 1) • Carbon dioxide and water vapor are greenhouse gases that absorb energy radiated from Earth's surface and release some of it back towards the Earth, increasing the surface temperature. (Atmosphere Lesson 3) • Oxygen is a highly reactive element involved in chemical reactions that release heat energy. Oxygen is important to humans because it helps to convert sugars into energy in the cells. (Atmosphere Lesson 5) • The creation and destruction of ozone in the stratosphere protects life on Earth from harmful ultraviolet radiation. (Atmosphere Lesson 6) • Nitrogen, like other substances, can have an effect on life because of its unique properties and because of the amount of it in the environment, which contributes to air pressure necessary for life functions. (Atmosphere Lesson 7)	• Scientific investigations may take many different forms, and scientists use many different instruments to collect data for analysis. • Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence. • Hypotheses are valuable, even if they turn out not to be true, if they lead to fruitful investigations. • Tools often give more information about things than can be obtained by just observing things without their help.

Suggested Timeline (45-minute periods):
Day 1: Engage and Explore Part I sections
Day 2: Explore Part 2
Day 3: Explain and begin Extend/Apply
Day 4: Extend/Apply and Evaluate sections

Materials and Equipment:

- Human Survival Chart (optional)
- A class set of Astro Journal Lesson 9: Atmospheric Science Mission Module (Most of this is optional, as it will be completed online, but unbolded sections are not online.)
- Signs or name tags for each student to indicate the element they represent
- 1-30 computers with Internet browser, Internet connection, JavaScript enabled and the Flash Player installed*
- 1 printer connected to the computers
- 1 "Y" cable for each computer
- Headphones for each student
- Atmospheric Chemist, Climatologist, and Meteorologist Career Fact Sheets
- Career Summaries
- Atmospheric Science Mission Module Walkthrough (optional)

Preparation:

- Duplicate a class set of Astro Journal Lesson 9: Atmospheric Science Mission Module, Atmospheric Chemist, Climatologist, and Meteorologist Career Fact Sheets and Career Summaries.
- Download and install the Flash Player 6 (or higher) plug-in on the computers. You can download the plug-in from http://www.macromedia.com/downloads/. Test these at http://astroventure.arc.nasa.gov by clicking "Atmospheric Science Mission."
- Gather and set up headphones and "Y" cables.
- Make an overhead transparency of Human Survival Chart (optional)

Differentiation:

Accommodations

For students who may have special needs:

- Pair advanced students with students who may need more guidance.
- Have students work with a partner on the Astro Journal writing or report orally to the teacher.
- Encourage students to talk about what they are learning as they go through the activity.

Advanced Extensions

Design your own mission to study the atmosphere of another planet or moon:

- What planetary body will you study? Why?
- What question will you try to answer?
- What is your hypothesis of what the answer to your question will be?
- What is the purpose of the mission?
- What scientific instruments will be used to gather data?
- What will the results of your research help us to learn?

Engage (approximately 25 minutes)

1. **Review the Atmospheric Science Training Module**
   - Question: What have we learned are the atmospheric conditions necessary to support human habitability?
   - *Answers may include: It seems like in the winter, whenever it is clear it is colder, and when its cloudy it gets warmer.*

   - Question: What three factors did we learn in Astronomy determine the surface temperature of a planet?
   - *Answer: The following atmospheric conditions are necessary for human habitability:*
     - *0.000001 to 20% water vapor*
     - *0.001 to 0.03% carbon dioxide*
     - *15 to 30% oxygen*
     - *More than 80 Dobson units ozone in the stratosphere*
     - *More than 5% nitrogen*

   - Question: Why are carbon dioxide and water vapor important to life?
   - *Answer: They are greenhouse gases that benefit humans by maintaining a stable, moderate temperature. These gases absorb heat that radiates from the Earth's surface, and release some of it back towards the Earth.*

   - Question: What temperature range do humans need?
   - *Answer: We need an average temperature above 0°C and below 100° C, where water can be a liquid. But we also need a temperature that is comfortable for our bodies to function—between 0° and 50°C.*

- Question: What important survival need does nitrogen help with?
- *Answer: Because nitrogen is inert, it can compose a large percentage of our atmosphere without causing negative effects to life, and is, thus, ideal as a large contributor to the air pressure on Earth necessary to support our bodies.*

- Question: What other important role does nitrogen play in survival?
- *Answer: Nitrogen is a fundamental building block of proteins, which are essential for life.*

- Question: Why is oxygen important for human survival?
- *Answer: Oxygen's tendency to react allows human cells to obtain energy from sugars and it makes up ozone.*

- Question: Why is ozone important to human survival?
- *Answer: Ozone molecules absorb ultraviolet radiation, preventing the ultraviolet radiation from reaching the Earth and harming animals and some plants.*

2. Introduce the purpose of the lesson.

- Say: Now that we know the atmospheric conditions necessary to support human habitability, we are going to investigate how scientists would go about determining if a planet met these requirements. We are going to simulate this process by examining the atmospheric conditions on Mars and Venus to see whether these planets can support human habitability.

3. Discuss the characteristics of scientific investigations.

- Question: What is the process that you've been using to carry out investigations in Astro-Venture? (You may want to identify a specific investigation that students carried out, such as the testing of the UV beads in Atmosphere Lesson 6.)
- *Answer: (Allow students to discuss their ideas about this. Students may say that they made a prediction or hypothesis, gathered data, and drew conclusions.)*

- Question: What did you use to gather information in different investigations? What do scientists use to collect data or to gather evidence?
- *Answer: (Allow students to discuss their ideas about this. They may say that they used rulers, thermometers, scales, magnifying glasses, and their eyes or other senses.)*

4. Introduce the scientific questions for this lesson.

- Say: As we simulate a scientific mission to examine the atmospheres of Mars and Venus, we will be paying attention to how scientists conduct scientific investigations and will be trying to answer the question:
  How do scientists go about investigating whether a planet has the necessary atmospheric conditions for human habitability?

- Question: How do you think NASA scientists go about conducting an investigation? Do you think they conduct an investigation the same way you have been?
- *Answer: (Allow students to discuss their ideas about this.)*

- Say: Think about these questions while you simulate this mission as NASA scientists.

- Question: So if we are going to investigate the atmospheres of Mars and Venus to see if they will support human habitability, what scientific questions are we trying to answer? What is your hypothesis about whether Mars' atmosphere's can support human habitability? What is your hypothesis about whether Venus' atmosphere's can support human habitability?

- Have students write their scientific questions and hypotheses in their Astro Journals.

  Note to Teacher: Students will be given the scientific questions in the online simulation and will be asked to type in their hypotheses.

5. Draw on prior knowledge and discuss possible methods for studying planetary atmospheres.

- Question: How might we tell whether a planet has an atmosphere?
- *Answer: (Allow students to discuss their ideas about this. Students will probably focus on visible evidence and may observe that a planet with an atmosphere may have visible clouds or a visible "halo" of light filtering through the atmosphere.)*

- Question: Can our atmosphere be felt?
- *Answer: (Students may observe that we can feel wind.)*

- Question: What happens when you go from a low place in the atmosphere to a higher place in the mountains or on a plane?
- *Answer: (Students may observe that they have felt their ears pop, that athletes may get out of breath, and that plastic bottles expand.)*

- Question: What causes this?
- *Answer: There is a change in pressure, because there is less atmosphere pushing on you as you go higher, and more as you go closer to the Earth's surface.*

- Question: So how might we be able to tell if a planet has an atmosphere if we cannot see an atmosphere?
- *Answer: We could measure the atmospheric pressure.*

- Question: What else will we want to find out about the atmospheres of Mars and Venus to determine if they are habitable?
- *Answer: We will want to know the composition of the atmospheres to see if the gas levels are within the range needed for human habitability.*

- Question: Besides pressure and amounts of gases, what other important role does atmosphere play for human habitability? (You could refer to the Human Survival Chart in Atmosphere Lesson 7 to help to answer this question.)
- *Answer: Atmosphere plays a role in the surface temperature of a planet, because greenhouse gases absorb heat and reradiate it back to a planet's surface.*

- Question: What methods do you think scientists might use to investigate the atmospheric pressure on Mars and Venus? The temperature? The air composition?
- *Answer: (Accept all answers. Use this as an opportunity to assess students' prior knowledge. Encourage students to discuss the kinds of information that scientists might need and the kinds of instruments that they might use to get this information.)*

- Question: What type of information about other planets can we get from the Earth? What are the advantages and disadvantages of that?
- *Answer: We can analyze the light we see through a telescope. The advantage is that it does not cost that much—just the cost of the telescope and equipment. The disadvantage is that the light goes through the*

layers of our atmosphere.

- Question: How can we get a telescope or other instrument above the Earth's atmosphere?
- *Answer: We could put the instrument on something we can control that is outside the Earth's atmosphere, such as an orbiting satellite—or on an airplane that flies above most of the Earth's atmosphere.*

Note to Teacher: NASA has used this method many times with telescopes such as Hubble, which orbits high above the Earth's atmosphere (600 km) and has allowed us to gather images of astronomical objects never seen before. Another orbiting telescope is the Spitzer Space Telescope. Similar planned missions are those of the Terrestrial Planet Finder and Kepler, which will also orbit high above the Earth's atmosphere and will allow us to search for Earth-size planets for the first time. Another technique that NASA has used is to fly an airplane with an onboard telescope in the Earth's upper atmosphere (12-15 km high). Kuiper was one such airplane. Currently NASA is developing a similar airplane called SOFIA (Stratospheric Observatory for Infrared Astronomy). To learn more about these missions, visit the following Web sites.

- Hubble Space Telescope http://hubble.nasa.gov
- Spitzer Space Telescope http://www.spitzer.caltech.edu/
- The Kepler Mission: http://www.kepler.arc.nasa.gov/
- Terrestrial Planet Finder http://tpf.jpl.nasa.gov
- Kuiper Airborne Observatory http://quest.arc.nasa.gov/lfs/lfshp.html
- SOFIA http://sofia.arc.nasa.gov/

6. Have students design a plan for answering their scientific question and testing their hypotheses.

- Say: As Astro-Venture Senior Atmospheric Scientists, you will be learning about some of the tools and methods scientists use to study planetary atmospheres, as you complete the online Astro-Venture Atmospheric Science Mission module. It is your mission to determine if Venus and Mars have the atmospheric conditions required for human habitation.

MISCONCEPTION: Upper elementary- and middle-school students may not understand experimentation as a method of testing ideas, but rather as a method of trying things out or producing a desired outcome. To bring out this misconception, ask students what the purpose of an experiment is. Ask them what is being tested and for what purpose. Emphasize that the purpose of the experiment is to test the hypothesis to see if it's true. Ask them if they test the hypothesis and find it's not true, what that means. If they say that that means the experiment failed, guide them to see the benefits of such a result. Stress that experiments need to be objective. Therefore, there is no such thing as a "failed" or "successful" experiment, but rather only scientific results that help us to answer a question. As students design the following plan, guide them to write plans that will give evidence to show whether the hypothesis is true or not.

- In their Astro Journals, have students record their plan on how they think they would go about investigating Mars and Venus' atmosphere to find out if they would support human habitability.

- Tell students that they will be completing the online Atmospheric Science Mission module to simulate the process that scientists would use to determine whether Mars and Venus have atmospheric conditions necessary to support human habitability.

Explore

Part 1 - (approximately 20 minutes)

1. **Discuss students' plans on how they would determine the habitability of Mars' and Venus' atmospheres.**
   - Discuss student hypotheses as to whether Mars and Venus have atmospheres that can support human life and their reasoning behind their hypotheses.
   - Discuss student plans for testing their hypotheses.

2. **Introduce students to the roles in the Astro-Venture Atmospheric Science Mission.**
   - Tell students that as they go through the Atmospheric Science Mission, they will be role-playing atmospheric scientists.
   - Ask students what kind of knowledge or expertise they might need to have on their team to carry out their mission.
   - Pass out the Atmospheric Chemist, Climatologist, and Meteorologist Career Fact Sheets and Career Summaries for students to read and discuss.

     Note to Teacher: The Career Fact Sheets and Career Summaries are included in the back of this lesson so that you can easily duplicate them for students. The first section of the online mission also provides this information, so students can view them online in PDF format or print them out from the Web site. You might consider having students go through the roles section on the computer during one class period and then embark on the mission section during a subsequent class period. Alternatively, you can do the roles off line with the class, and they can then skip this section on the computer to help cut down on the time students will need to be online.
   - Have students identify the role or roles they will take on in the mission. Have them record their role or roles in their Astro Journals. Tell students that they will need to remember their role or roles, as each role will be asked to use their expertise during different parts and will take control of the mouse for that activity.

     Note to Teacher: There are three roles for this module; however, we found in testing that students worked better in pairs than in threes. We suggest having students work in pairs and having one student take on two roles, as all three roles must be filled in the mission. Career Summaries of the roles and Career Fact Sheets are found at the end of this lesson.
   - Tell students that their special knowledge for their area will be needed during certain parts of the mission, and they will need to be in control of the mouse when prompted.

3. **Introduce students to the Atmospheric Science Mission.**
   - Tell students that they will be embarking on an important mission in their chosen roles to analyze data from Mars and Venus and determine if they meet the atmospheric requirements for human survival and why or why not.

Explore

Part 2 - (approximately 45 minutes)

1. **Introduce students to the Astro-Venture Atmospheric Science Mission module.**
   - Tell students that they will use their Astro-Venture Academy instruments to determine whether Mars and Venus have atmospheres that support human survival.
   - Tell students that as they conduct this mission, they should think about the process and techniques that they are using.
   - Tell students that they will go through the module as Astro-Venture Senior Atmospheric Scientists and will use the scientific inquiry process. They will also have help from several NASA scientists.

     Note to Teacher: The module relies on audio, so we suggest that you obtain headphones for each computer. If pairs of students will share a computer, we suggest using "Y cables" that allow you to plug a pair of headphones into one computer.

2. **Have students engage in the Atmospheric Science Mission module individually, in pairs, small groups, or as a class. If they are in groups of three, each student can take on a scientist's role.**

MISCONCEPTION: Students of all ages find it difficult to distinguish between a theory and the evidence for it, or between description of evidence and interpretation of evidence. The following and later discussion can help to identify and confront this misconception. When discussing results and conclusions, encourage students to differentiate these as they communicate by saying or writing, "My conclusions are…" and "The evidence I have to support these conclusions are…"

- You may want to discuss with students the difference between a hypothesis and evidence and the difference between results and conclusions before they begin their investigation.
  - Question: You have written down hypotheses of what you think the answers to your scientific questions are. Are the hypotheses correct?
  - *Answer: We do not know yet.*
  - Question: How will we know if they are true or not?
  - *Answer: We need to gather some evidence that proves them true or proves them not true.*
  - Question: What is the difference between the data we gather and the conclusions we make?
  - *Answer: The data are just information or evidence. Our conclusions are made once we interpret the data or decide what the data mean.*
  - Question: Can different scientists have different conclusions with the same results?
  - *Answer: Yes, scientists might interpret the data differently. They may not agree on what the data means.*
- Students can access the module at http://astroventure.arc.nasa.gov and click on "Atmospheric Science Mission."

- Filling out the instruments, data, and conclusions for each section in their paper Astro Journal is optional. These can be recorded and printed online, but if students are unable to print, the paper journal is provided as another option.

  Note to Teacher:
  - You will want to have accessibility to a printer, so that students can print their newspaper articles and Astro Journals at the end of the module. These can be used for evaluation purposes.
  - If you want to take the whole class through the module using one computer, use the Atmospheric Science Mission Walkthrough as a guide.
  - Most students should be able to complete the activity in a class period. However, if a student does not complete the module, it is possible to come to where they left off by either writing down the URL of the page they are on, or bookmarking the page and writing down the name of the bookmark. This is NOT possible in the training modules, but is an enhancement added to the mission modules. However, any information stored in the Astro Journal will not be permanently stored on the hard drive, and therefore won't be available to students if they quit the browser and come back later.

- All of the information in the Atmospheric Science Mission Module is accurate based on the most recent NASA data available at the time of development.

Explain (approximately 30-40 minutes)

1. Have students discuss/share their results and conclusions.

Note to Teacher: As you discuss the following, you may want students to report on their area of expertise based on the role they held. One way to do this is to have students meet in three groups by area of expertise to discuss and decide how to present their results.

- Question: What is the difference between the statements you wrote down as your results and the statements you wrote down as your conclusions?
- *Answer: Our results are observations or facts. Our conclusions are how we interpret the facts in terms of answering our scientific question.*

- Question: Looking at your results, what conclusions did you make about whether the atmosphere on Mars can support human life? What evidence do you have to support this conclusion?
- *Answer: Our conclusion is that Mars cannot support human life. The evidence we have to support this is that the atmospheric pressure and temperature on Mars are too low. Also, Mars has no ozone or oxygen and does not have enough water vapor.*

- Question: Looking at your results, what conclusions did you make about whether the atmosphere on Venus can support human life? What evidence do you have to support this conclusion?
- *Answer: Our conclusion is that Venus cannot support human life. The evidence we have to support this is that the atmospheric pressure and temperature on Venus are too high. Venus has no water vapor, ozone or oxygen.*

2. Have students complete the Final Conclusions on Scientific Investigations section of their Astro Journals.

3. Discuss what students learned about how scientists conduct an investigation.

- Question: What did you, as scientists, do in carrying out your investigation?
- *Answer: (Answers will vary, but should include gathering data or making observations to help to answer a question and test a hypothesis. They should also include using logical reasoning to draw conclusions from these results.)*

- Question: What instruments did you use to collect data or to gather evidence?
- *Answer: We used a spectroscope, a barometer, and a thermometer.*

- Question: What would happen if scientists didn't have these kinds of tools?
- *Answer: If we didn't have these tools, we could not get as much information about other planets or we would have to think of other ways to get the information.*

- Question: What did the data look like and how did you interpret it?
- *Answer: (Students should describe the graphs they saw and what they meant.)*

- Question: What's the same and what's different between how you do an investigation and how NASA scientists do?
- *Answer: (Answers will vary. Students may observe that scientists use more sophisticated and expensive equipment and conduct much larger investigations than students have. Students may also observe that they form questions, test hypotheses, gather data, use good reasoning and evidence to interpret their data, and draw conclusions just like scientists do.)*

MISCONCEPTION: A commonly held misconception is that there is a fixed set of steps that scientists always follow in carrying out an investigation. While it is always important for scientists to collect relevant evidence and to base their conclusions on logical reasoning, there is no fixed order or process that must be used in science. The following discussion will help with this misconception.

- Question: Thinking back on the different investigations you have carried out, are all investigations identical?

  Note to Teacher: You might list different investigations and discuss how each was conducted. For example, in the Atmospheric Science Training module, students changed one factor (or variable) at a time and observed the effect on Earth. In Atmospheric Science Lesson 4, they mixed substances together and observed the chemical properties of the new substance. In the Atmospheric Science Mission, they took temperature, composition, and pressure readings to gather and graph data over time on different planets.

- *Answer: Scientific investigations can take many different forms. Scientists may be able to compare reactions in a laboratory or may make observations on Earth or in space over time.*

- Question: So what can we conclude about how scientists conduct an investigation?
- *Answer: Although there is not a fixed set of steps that all scientists follow, there are some things that are true for all investigations. Scientists use a wide variety of instruments to collect data in investigations, and they use this data and logical reasoning to draw conclusions that help them answer questions and test hypotheses.*

- Question: If a scientist tests a hypothesis and it turns out not to be true, does that mean that she wasted her time?
- *Answer: No. Even if a hypothesis is proven to be wrong, we still learn something that helps to build new scientific knowledge.*

Note to Teacher: You might give students an example of how an incorrect hypothesis can be helpful. Here's one example:

After the warming trends of the planet had been discovered, atmospheric scientists formed the following hypothesis about greenhouse gases emitted into the atmosphere:

All of the increases in greenhouse gas concentrations, including carbon dioxide, contribute to the greenhouse effect and global warming of the planet.

To test the hypothesis, scientists built a computer model of how the atmosphere should have warmed during this period using the knowledge of how carbon dioxide contributes to atmospheric warming and knowing how much carbon dioxide was released into the atmosphere during the last 20 years. They expected that the predicted temperature increases due to the greenhouse gases during the 20 years would be close to the observed temperature increase. It turned out that the model-predicted temperature was higher than that observed. After careful interpretations of the study, the scientists concluded that the atmosphere-ocean system uptakes more CO_2 than they originally predicted, and not all of the CO_2 released into the atmosphere contributes to global warming.

Therefore, the initial hypothesis of the scientists was not exactly correct and it lead to an important discovery that the atmosphere-ocean system is capable of taking up more CO_2 when more CO_2 is released into the atmosphere.

Extend/Apply (approximately 30-40 minutes)

1. Have students complete the Astrobiology/Atmospheric Science Missions section of their Astro Journals.

- Students visit NASA Web sites to research current Astrobiology missions.

Missions that are in progress or were planned at the time this lesson was written include:

- Mars Exploration Rovers http://marsrovers.jpl.nasa.gov/home/index.html
- Kepler Mission http://www.kepler.arc.nasa.gov/
- Mars Odyssey http://marsprogram.jpl.nasa.gov/odyssey/
- Mars Science Lander 2009 http://nssdc.gsfc.nasa.gov/planetary/mars_2003_05.html
- Terrestrial Planet Finder, LifeFinder http://tpf.jpl.nasa.gov
- Cassini/Huygens Probe http://saturn.jpl.nasa.gov/index.cfm
- Mars Global Surveyor http://marsprogram.jpl.nasa.gov/mgs/
- Mars Reconnaissance Orbiter http://marsprogram.jpl.nasa.gov/mro/
- Virtual Planet Laboratory http://astrobiology.ipac.caltech.edu/
- Spitzer Space Telescope http://www.spitzer.caltech.edu/
- Stardust http://stardust.jpl.nasa.gov/
- Jupiter Icy Moons Orbiter http://www.jpl.nasa.gov/jimo/mission.cfm
- NASA Scout Missions: Sample Collection for Investigation of Mars (SCIM), Aerial Regional-scale Environmental Survey (ARES), Phoenix, Mars Volcanic Emission and Life Scout (MARVEL) http://nssdc.gsfc.nasa.gov/planetary/mars_2003_05.html

Other useful websites:

- NASA Astrobiology Institute http://nai.arc.nasa.gov/
- JPL Space Missions Page http://www.jpl.nasa.gov/missions/
- Astrobiology At NASA http://astrobiology.arc.nasa.gov/
- National Space Science Data Center http://nssdc.gsfc.nasa.gov/planetary/
- Chronology of Lunar and Planetary Missions http://nssdc.gsfc.nasa.gov/planetary/chrono.html
- Astrobiology Missions http://astrobiology.arc.nasa.gov/missions/index.cfm
- PlanetQuest http://planetquest.jpl.nasa.gov/

Evaluate (approximately 15 minutes)

1. **Have students share the descriptions of the NASA missions using scientific inquiry to explain these missions. To guide this discussion, ask the following questions:**
   - What form of investigation will/did the NASA scientists use to explore their question?
   - What evidence will/did they collect to answer the question and test the hypothesis?
   - If the mission is complete, what conclusions did they make?
   - If the mission is complete, how did they use the evidence to support their conclusions?

2. **Collect students' Astro Journals and evaluate them to ensure that they have each mastered the major concepts:**
   - Scientific investigations may take many different forms, and scientists use many different instruments to collect data for analysis.
   - Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.
   - Hypotheses are valuable, even if they turn out not to be true, if they lead to fruitful investigations.
   - Tools often give more information about things than can be obtained by just observing things without their help.

3. **Connect back to the overall purpose of Astro-Venture and the unifying concept of systems.**
   - Question: If we should find a planet or moon outside our solar system that does meet the atmospheric conditions required for human habitability, would that mean that the planet would be habitable to humans?
   - *Answer: Not necessarily. The planet would also need to meet the astronomical, geological, and biological requirements for human habitation.*

4. **Bridge to next unit.**
   - Question: We've learned about the importance of the gases in our atmosphere for human habitability, and we've learned about the importance of astronomical characteristics of our solar system for human habitability. If a planet has these astronomical characteristics and atmospheric characteristics, is it habitable to humans?
   - *Answer: Not necessarily. There are still geologic and biological characteristics that the planet must also have.*
   - Say: In the next unit we will learn about the geological characteristics that are necessary for human survival.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the "conceptual flow" and reflect on the progression of learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

1. Scientific Questions:

2. Hypotheses:

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

3. Plan for testing your hypotheses:

4. What role or roles will you take on for this mission?

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

The following questions are asked online with the exception of question "1" for each section. If you are unable to print from the computer, you may use the following charts and questions to record your observations.

Mars Temperature

1. Instruments used:

2. How do the winter temperatures on Mars compare to temperatures on Earth?

- ☐ a. Much colder than Earth.
- ☐ b. About the same as Earth.
- ☐ c. Much hotter than Earth.

3. How do the summer temperatures on Mars compare to temperatures on Earth?

4. What season has the highest temperature?

- ☐ a. Winter
- ☐ b. Spring
- ☐ c. Summer
- ☐ d. Fall

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

5. What season has the lowest temperature?

- ☐ a. Winter
- ☐ b. Spring
- ☐ c. Summer
- ☐ d. Fall

Conclusions

6. Are the temperatures on Mars ever habitable to humans? Why or why not?

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

Venus Temperature

1. Instruments used:

2. How do the winter temperatures on Venus compare to temperatures on Earth?

- ☐ a. Much colder than Earth.
- ☐ b. About the same as Earth.
- ☐ c. Much hotter than Earth.

3. How do the summer temperatures on Venus compare to temperatures on Earth?

- ☐ a. Much colder than Earth.
- ☐ b. About the same as Earth.
- ☐ c. Much hotter than Earth.

Conclusions

4. Based on what you've observed, are the temperatures on Venus habitable to humans? Explain.

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

Mars Pressure

1. Instruments used:

2. During which season is the air pressure on Mars the highest?

- ☐ a. Winter
- ☐ b. Spring
- ☐ c. Summer
- ☐ d. Fall

3. During which season is the air pressure on Mars the lowest?

- ☐ a. Winter
- ☐ b. Spring
- ☐ c. Summer
- ☐ d. Fall

4. How does the air pressure on Mars compare to air pressure on Earth?

- ☐ a. Much lower than Earth.
- ☐ b. About the same as Earth.
- ☐ c. Much higher than Earth.

Conclusions

5. Based on what you observed, is the air pressure on Mars habitable to humans? Why or why not?

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

Venus Pressure

1. Instruments used:

2. How does the winter air pressure on Venus compare to air pressure on Earth?

- ☐ a. Much lower than Earth.
- ☐ b. About the same as Earth.
- ☐ c. Much higher than Earth.

3. How does the summer air pressure on Venus compare to air pressure on Earth?

- ☐ a. Much lower than Earth.
- ☐ b. About the same as Earth.
- ☐ c. Much higher than Earth.

Conclusions

4. Based on what you've observed, is the air pressure on Venus habitable to humans? Why or why not?

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

Atmospheric Composition

1. Instruments used:

2. Data
Check the boxes to show what gases each planet has in its atmosphere.

	Water Vapor	Ozone	Carbon Dioxide
Mars	☐	☐	☐
Earth	☐	☐	☐
Venus	☐	☐	☐

3. Select two reasons why water vapor is important to human habitability.

- ☐ a. It's a greenhouse gas.
- ☐ b. It means the planet's surface might have liquid water.
- ☐ c. It protects us from ultraviolet radiation.

4. Select two reasons why ozone is important to human habitability.

- ☐ a. It protects us from ultraviolet radiation.
- ☐ b. It's a greenhouse gas.
- ☐ c. It means the planet's atmosphere has a lot of oxygen.

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

5. Select two reasons why carbon is dioxide important to human habitability.

- ☐ a. It means the planet's surface has liquid water.
- ☐ b. It's a greenhouse gas.
- ☐ c. Plants need it for photosynthesis.

Conclusions

6. How does the composition of Mars' atmosphere compare to the atmosphere of Earth? How would these differences affect this planet's habitability?

7. How does the composition of Venus' atmosphere compare to the atmosphere of Earth? How would these differences affect this planet's habitability?

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

Final Conclusions on Scientific Investigations

1. Based on what you've learned, do Mars and Venus have atmospheres that could support human life? Why do you think that?

Mars

Venus

The following questions are not asked online; you need the worksheets to answer them.

2. What did you learn about how scientists conduct an investigation?

3. How are the investigations you did the same as the ones NASA scientists do?

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

4. How are the investigations you did different than the ones NASA scientists do?

5. Are all investigations exactly the same? Explain.

6. If a scientist tests a hypothesis, and it turns out not to be true, has she wasted her time? Explain.

7. How did you like the role you played? What do you like about this job? What other information would you like to learn about this job?

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

Astrobiology Missions

Visit NASA Web sites to find missions that are looking for Earth-size planets, conditions for life on other planets or signs of life on other planets. Describe these missions using the following guidelines.

- Mars Exploration Rovers http://marsrovers.jpl.nasa.gov/home/index.html
- Kepler Mission http://www.kepler.arc.nasa.gov/
- Mars Odyssey http://marsprogram.jpl.nasa.gov/odyssey/
- Mars Science Lander 2009 http://nssdc.gsfc.nasa.gov/planetary/mars_2003_05.html
- Terrestrial Planet Finder, LifeFinder http://tpf.jpl.nasa.gov
- Cassini/Huygens Probe http://saturn.jpl.nasa.gov/index.cfm
- Mars Global Surveyor http://marsprogram.jpl.nasa.gov/mgs/
- Mars Reconnaissance Orbiter http://marsprogram.jpl.nasa.gov/mro/
- Virtual Planet Laboratory http://astrobiology.ipac.caltech.edu/
- Spitzer Space Telescope http://www.spitzer.caltech.edu/
- Stardust http://stardust.jpl.nasa.gov/
- Jupiter Icy Moons Orbiter http://www.jpl.nasa.gov/jimo/mission.cfm
- NASA Scout Missions: Sample Collection for Investigation of Mars (SCIM), Aerial Regional-scale Environmental Survey (ARES), Phoenix, Mars Volcanic Emission and Life Scout (MARVEL) http://nssdc.gsfc.nasa.gov/planetary/mars_2003_05.html

Other useful websites:

- NASA Astrobiology Institute http://nai.arc.nasa.gov/
- JPL Space Missions Page http://www.jpl.nasa.gov/missions/
- Astrobiology At NASA http://astrobiology.arc.nasa.gov/
- National Space Science Data Center http://nssdc.gsfc.nasa.gov/planetary/
- Chronology of Lunar and Planetary Missions http://nssdc.gsfc.nasa.gov/planetary/chrono.html
- Astrobiology Missions http://astrobiology.arc.nasa.gov/missions/index.cfm
- PlanetQuest http://planetquest.jpl.nasa.gov/

1. Title of the mission:

2. Web site address where information on this mission was found:

3. Scientific question being studied by this mission:

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

4. Scientific hypothesis that scientists theorize they will find on this mission:

5. Materials and instruments scientists will use to gather data:

6. Methods and procedure scientists will use to gather data:

Astro Journal Lesson 9: **Atmospheric Science Mission Module**	**Name:**
Class/Period:	**Date:**

7. If the mission is completed, report the results that were found. Was their hypothesis proven correct or incorrect?

8. If the mission is completed, what conclusions did scientists draw? What can we learn from the results?

Astro-Venture Atmospheric Science Mission Walkthrough

Introduction

1. When students click "Atmospheric Science Mission" they will first be given the opportunity to review the main concepts they should have mastered from Atmospheric Science Training. This is given in the form of four multiple choice questions, which students can either answer and submit to see the correct answers or they can skip by clicking "Skip the quiz" in the bottom left corner. The "Review" arrow shows up if they answer any question incorrectly, and will take them back to the Atmospheric Science Training module. However, they are also given a "Continue" arrow that allows them to proceed to the mission.

2. When students click either "Skip the quiz" from the first screen or "Continue" from the second screen, they will see an animated introduction to the mission. Astro-Ferret will outline the inquiry steps that students will take to complete their mission. Clicking on the circular arrow will allow students to replay this introduction.

   Note to Teacher: The Accessibility Notes button brings up a pop-up window with all of the audio narration for deaf students and for those students who may benefit from seeing this text. The Accessibility Notes also provide descriptions of all graphics and animations for blind students.

3. Mission: Research Roles When students click the arrow on the introduction screen, they will enter the page for the roles. Students can click each role to learn more about that career and a NASA scientist in that occupation. They can read a short description of the career and click on the "Let's Meet_____" to open a pop-up and hear an audio clip description from the scientist. From the pop-up window, they can click on "Career Fact Sheet (PDF)" to get more detailed information about the scientist.

   Note to Teacher: Students will not likely have time to complete the mission in one class period if they spend a lot of time reviewing the career information, so it is suggested that this be reviewed either off-line or in two separate class periods.

4. Mission: Choose Your Role When students click "Continue" they will be asked to enter a name next to each role to determine who will play each role. Since students will likely be working in pairs or alone, students will have to play more than one role. Each role must be filled before students can continue. The names are not stored but are used to print on the journal at the end, so it is clear whom each journal belongs to.

   Note to Teacher: Emphasize with students that they will need to remember their role(s), as they will be asked to take control of the mouse when each role is needed.

5. Form Your Hypotheses When students submit their roles, they will be taken to the hypotheses page where they will need to type in one hypothesis for Mars and one for Venus on whether they think the atmospheres on those planets will support human life and why.

   Note to Teacher: Journal responses will not be saved, so students either need to complete the mission in one sitting, so they can print their journal responses at the end or they will need to use the paper version of the journal provided in this lesson.

6. Mission Control After submitting their hypotheses, students will enter mission control where they can choose to look at temperature, pressure, or composition.

Temperature

1. Choose a Planet: Temperature When students choose "Temperature" from mission control, they will be taken to a screen where they can select Mars or Venus. After completing one, the program will automatically send them to the other so that both are completed. The process is similar for both planets.

2. Cool Facts A cool fact about Mars or Venus is given. All of the cool facts from the module are listed at the end of this walk through.

3. Introduction Astro gives an introduction about the spacecraft and instruments used and asks for the meteorologist to take control of the mouse. Students need to click "Access Data" to proceed. The instrument used to measure temperature is a thermometer.

4. Temperature Data Students are asked to analyze seasonal high and low temperature data. They can scroll the reference chart for comparable temperatures of objects and places on Earth. They can click on Tool for an animated explanation of Celsius, graphing, how to read the graphs and how to compare them to the reference chart. Students can also click on Hint for an audio hint from the NASA expert. After considering all of this, students are asked to answer multiple choice or open-ended questions at the bottom of the screen. If they submit an incorrect multiple-choice answer, a pop-up will prompt them to try again. If they do not enter enough text (at least ten characters) they will be prompted to enter more of an explanation. If they submit a correct answer, they will be provided with a summarizing sentence of the correct conclusion and a "Continue" button to take them to the next question.

5. Scientist Feedback: Temperature The last open ended question will ask them to draw conclusions about the habitability of temperatures on Mars or Venus. When they submit this response, they will be taken to a screen where the NASA expert will provide text and audio feedback on habitability of Mars or Venus.

6. Temperature Completion After completing both the Mars and Venus sections, students will be sent to a screen where they have the choice of clicking "Learn More" or returning to "Mission Control" to select a new area to analyze.

7. Learn More: Temperature If students choose to visit this screen, they will go to a series of screens of text, narration, and graphics that describe a relevant upcoming NASA mission. They will be referred to a Web address of this mission, if they want to learn more about it. They will then be given a "Return" arrow that will send them back to the "Temperature Completion" screen from which they can return to "Mission Control."

Pressure

1. Pressure Introduction When students choose "Pressure" from mission control, they will be taken to an animation that explains how pressure changes with altitude and the effect of pressure changes on the human body.

2. Choose a Planet: Pressure When students click "Continue" from the introductory animation, they will be taken to a screen where they can select Mars or Venus. After completing one, the program will automatically send them to the other so that both are completed. The process is similar for both planets.

3. Cool Facts A cool fact about Mars or Venus is given. All of the cool facts from the module are listed at the end of this walk through.

4. Introduction Astro gives an introduction about the spacecraft and instruments used and asks for the climatologist to take control of the mouse. Students need to click "Access Data" to proceed. The instrument used to measure temperature is a barometer.

5. Pressure Data Students are asked to analyze seasonal high and low pressure data. They can scroll the reference chart for comparable pressures of places on Earth. They can click on Tool for an animated explanation of a barometer, millibars, graphing, how to read the graphs and how to compare them to the reference chart. Students can also click on Hint for an audio hint from the NASA expert. After considering all of this, students are asked to answer multiple choice or open-ended questions at the bottom of the screen. If they submit an incorrect multiple-choice answer, a pop-up will prompt them to try again. If they do not enter enough text (at least ten characters) they will be prompted to enter more of an explanation. If they submit a correct answer, they will be provided with a summarizing sentence of the correct conclusion and a "Continue" button to take them to the next question.

6. Scientist Feedback: Pressure The last open ended question will ask them to draw conclusions about the habitability of pressures on Mars or Venus. When they submit this response, they will be taken to a screen where the NASA expert will provide text and audio feedback on habitability of Mars or Venus.

7. Pressure Completion After completing both the Mars and Venus sections, students will be sent to a screen where they have the choice of clicking "Learn More" or returning to "Mission Control" to select a new area to analyze.

8. Learn More: Pressure If students choose to visit this screen, they will go to a series of screens of text, narration, and graphics that describe a relevant upcoming NASA mission. They will be referred to a Web address of this mission, if they want to learn more about it. They will then be given a "Return" arrow that will send them back to the "Pressure Completion" screen from which they can return to "Mission Control."

Composition

1. Composition Introduction When students choose "Composition" from mission control, they will be taken to an animation that explains how data will be collected using a spectrometer above the Earth's atmosphere. Astro-Ferret then asks for the atmospheric chemist to take control of the mouse.

2. Choose a Planet: Composition After the introduction, students will automatically be taken to a screen where they can select Mars or Venus using either the arrows on their keypad or by clicking the arrows on the screen to maneuver the crosshairs over the planet of their choice. Once the target is over the planet and turns yellow, they can click "Take Spectrum" to bring up the spectrum of that planet's atmosphere. They will then need to click "Take another reading" to return to the target screen so that they can maneuver the target over the other planet and take its spectrum. After taking this second spectrum, they will need to click "Analyze Spectrum" to continue.

3. Composition Data Students are asked to analyze composition data. They can scroll the reference chart for the spectra of each individual gas and look for comparable dips in the atmosphere of each planet. Students can click on Tool for an animated explanation of a spectrometer, spectral lines, spectrogram graphs, and how to read and interpret these graphs found in the reference chart. Students can also click on Hint for an audio hint from the NASA expert. After considering all of this, students are asked to check the planets that have each gas and answer multiple choice questions open-ended questions at the bottom of the screen. If they submit an incorrect multiple-choice answer, a pop-up will prompt them to try again. If they do not enter enough text (at least ten characters) they will be prompted to enter more of an explanation. If they submit a correct answer, they will be provided with a summarizing sentence of the correct conclusion and a "Continue" button to take them to the next question.

Note to Teacher: The dips on the graphs may be difficult to interpret. The signature of each planet shows all the gases, and they are comparing to a graph of one gas at a time, so the graphs don't look exactly the same. The Tool button animation shows two examples that may help students with this interpretation. Also, note that the questions in this section are more challenging than the other sections, because more than one planet may have a given gas. Students must check all planets that have a given gas.

4. Scientist Feedback: Composition The last two open ended questions will ask them to draw conclusions about the habitability of compositions on Mars and Venus. When they submit each response, they will be taken to a screen where the NASA expert will provide text and audio feedback on habitability of Mars or Venus.

5. Composition Completion After completing the entire section, students will be sent to a screen where they have the choice of clicking "Learn More" or returning to "Mission Control" to select a new area to analyze.

6. Learn More: Composition If students choose to visit this screen, they will go to a series of screens of text, narration, and graphics that describe a relevant upcoming NASA mission. They will be referred to a Web address of this mission, if they want to learn more about it. They will then be given a "Return" arrow that will send them back to the "Composition Completion" screen from which they can return to "Mission Control."

Congratulations

When students click "Mission Control" after completing all three sections, they will be sent to a Congratulations page. They will be asked to click "Continue" to enter their final results.

Update/Correct Hypotheses

Students are asked to type in their results on what they learned about the habitability of the atmospheres of Mars and Venus. They can click "Access my journal" to open a pop up of all of the answers they entered throughout the mission. Once they have entered their results, they need to click "Submit."

Feedback on Mars Hypothesis

When students click "Submit" they will be brought to a screen with audio and text summarizing feedback on the habitability of Mars' atmosphere.

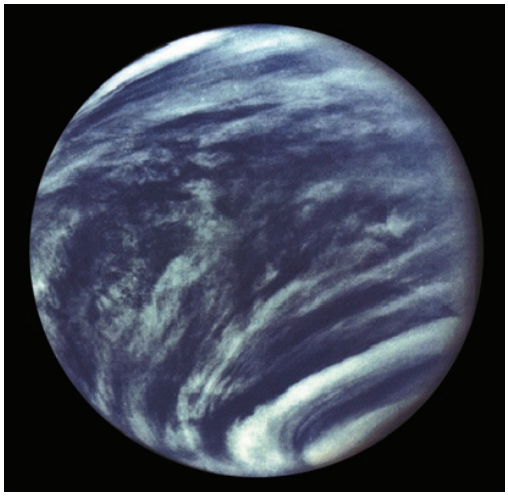
Feedback on Venus Hypothesis

When students click "Continue" they will be brought to a screen with audio and text summarizing feedback on the habitability of Venus' atmosphere.

Print Menu

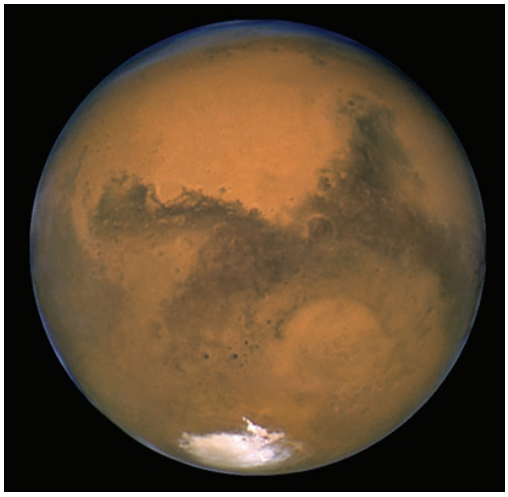
When students click "Continue" they will be brought to a Print Menu screen where they can click "Print Journal" to open a pop-up page of all of their journal responses. At the top of this pop up, students can click "print journal" to print this page. Students can also click "Print Newspaper" to bring up an article in an HTML page about their mission that can be read and printed. Finally, they can click "AV Main Menu" to return to the Astro-Venture home page. NOTE that once students exit to the main menu, their journal data will be lost.

Cool Facts about Venus!



- A day on Venus is longer than its year!
- Venus rotates in the opposite direction of Earth!
- Venus has no moons!
- Because Venus and Earth are almost the same size, Venus is called Earth's "twin."
- Venus was named after the Roman goddess of love and beauty.
- The surface features on Venus are named after famous women.
- Venus is the brightest object in the sky except for the Sun and moon.
- Venus is also known as the "morning star" and the "evening star."
- We have pictures of the Venusian surface from Russian space missions!
- Venus' surface is so hot, it can melt lead!
- Venus has clouds made of sulfuric acid!
- The pressure on Venus is so high, that it is almost the same as being 1 kilometer deep the ocean!
- Venus has the hottest average surface temperature of any planet in the solar system.
- Venus is the only planet that rotates clockwise. To an observer on Venus, the Sun would rise in the west and set in the east.
- The surface of Venus has lots of volcanoes, mountains, and big cracks.
- Venus receives twice as much of the Sun's light as does Earth.
- It takes light from the Sun 5.9 minutes to reach Venus.
- Wind speeds on Venus average 240 mph.
- At least 85% of the Venusian surface is covered with volcanic rock

Cool Facts about Mars!



- *Mars has huge dust storms that sometimes cover the entire planet!*
- *The polar caps on Mars grow and shrink with the seasons!*
- *A year on Mars is almost twice as long as a year on Earth!*
- *The days on Mars are called "sols."*
- *Mars might have liquid water on its surface!*
- *The largest canyon on Mars, called Valles Marineris, is as long as the United States!*
- *Mars was named after the Roman god of war.*
- *Mars has two moons, called Phobos and Deimos, which mean "fear" and "panic."*
- *The month of March was named after the planet Mars.*
- *Tuesday (Martes in Spanish) was named after the planet Mars.*
- *Mars gets it red surface from rust.*
- *The largest volcano on Mars is almost 3 times as tall as Mt. Everest!*
- *Mars has permanent ice caps at both poles.*
- *Percival Lowell thought he saw water canals on Mars!*
- *Some meteorites on Earth are actually pieces of Mars!*
- *Some scientists think there might be fossils in a Martian meteorite!*
- *The gravity on Mars is one-third of Earth's.*
- *It takes light from the Sun 12.5 minutes to reach Mars.*
- *Martian air contains only about 1/1,000 as much water as the air on Earth.*

Career Summaries

Atmospheric Chemist

An Atmospheric Chemist is a scientist that studies the different molecules in a planet's atmosphere. They investigate how these molecules interact with each other and the rest of the planet. They make observations and collect data to understand how the atmosphere reacts to sunlight and many parts of the Earth's surface including soil, snow, vegetation, and oceans. Atmospheric Chemists use many tools, such as spectrometers, computer models and simulations, satellite data, and spacecraft instruments.

Climatologist

Climatologists collect data and make predictions about climate patterns. They study how Earth's climate changes with time. They use glacial ice cores, tree rings, and other sources of information to learn about the climate in Earth's past. They use computer software programs that help to model Earth's climate. They do research to find out if humans are affecting Earth's present and future climate. Some Climatologists study climates on other planets. Climatologists use tools such as thermometers, barometers, computer models and simulations, satellite data, and spacecraft instruments.

Meteorologist

A Meteorologist collects weather data and makes predictions about developing weather patterns. They tell air traffic controllers and pilots about weather hazards such as thunderstorms, turbulence, tornadoes, icing, and flooding. They release public weather advisories for vehicles, aircraft, and watercraft. They also participate in weather-related research projects that help to provide more accurate forecasting methods over long time periods. Meteorologists use many tools, such as thermometers, barometers, computer models, and satellite data.

National Aeronautics and Space Administration

Educational Product	
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ET-2004-10-138-ARC

Educational Topic

Atmospheric Chemist

Related Job Titles:

Atmospheric Scientist, Environmental Scientist, Air Quality Analyst, Meteorologist, Atmospheric Physicist

Job Description:

Atmospheric chemistry is a multi-disciplinary field that is a sub-set in the broader field of atmospheric science. Atmospheric Chemists are interested in the chemical composition of the atmosphere and how the chemical constituents of the atmosphere interact with each other. Atmospheric Chemists make oberservations and collect data to understand how the atmosphere reacts and changes to sunlight and many parts of the Earth's surface including soils, vegetation, oceans, ice and snow. Some Atmospheric Chemists analyze the composition of our current atmoshere to compare with past data to understand the local, regional, and global impacts of our industrial practices. Atmospheric Chemists can also help gain an understanding of a distant planet's composition because they can analyze the chemistry of a planet's atmosphere remotely.

Interests / Abilities:

- Are you interested in the world around you and the processes that effect our planet?
- Can you perform calculations quickly with great accuracy?
- Are you patient when it comes to completing forms requiring detailed information?
- Do you like to solve logic puzzles?
- Are you a good problem solver?

Suggested School Subjects / Courses:

- Chemistry
- Math (algebra, trigonometry)
- Physics
- Meteorology
- Statistics
- Computer modeling
- Environmental studies
- Electronics

Education / Training Needed:

The minimum education required for this position is a bachelor's degree in Atmospheric Sciences or Chemistry from an accredited college or university. Experience in hands-on laboratory techniques is extremely helpful for this job. To do research, at minimum a master's degree is required, and a Ph.D. is highly desired for this position.

Areas of expertise:

- *Synoptic:* analyze data from satellites, radar, and surface-observing instruments
- *Research:* study atmospheric chemistry, refine theories and improve mathematical/computer models of atmospheric composition and its impacts on the planet
- *Environmental:* monitor pollution from traffic and industry and its effects on the planet

Additional Resources:

- **American Meteorological Society**
  http://www.ametsoc.org/AMS
- **Astrobiology Summer Academy**
  http://academy.arc.nasa.gov/
- **Atmospheric Chemistry and Physics Interactive Science Journal**
  http://www.copernicus.org/EGU/acp/
- **Education Pays Calculator**
  http://www.educationpays.org/calc.asp
- **Graduate Student Researchers Program**
  http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Graduate.Student.Researchers.Program.Brochure/.index.html
- **MATHCOUNTS Competition**
  http://mathcounts.org/
- **Minority University Research and Education Programs**
  http://mured.nasaprs.com/
- **NASA Cooperative Education Program for college students**
  http://spacelink.nasa.gov/Educational.Services/NASA.Education.Programs/Student.Support/NASA.Cooperative.Education.Program/.index.html
- **NASA SHARP Internship Program for high-schoolers**
  http://www.mtsibase.com/sharp/
- **NASA Student Employment**
  http://nasajobs.nasa.gov/stud_opps/employment/index.htm
- **NASA Student Involvement Program student contests**
  http://www.nsip.net/index.cfm

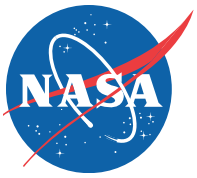
What can I do right now?

- Buy a chemistry set and learn how different substances interact with each other.
- Set up your own weather station and provide your local radio station with a daily report.
- Read newspapers and magazines to understand how governments and industries make policies related to atmospheric composition.
- Take samples of rain or soil in your neighborhood and analyze them using water and soil test kits from your local hardware store.

- **NASA Jobs**
  http://nasajobs.nasa.gov/
- **National Center for Atmospheric Research -Atmospheric Chemistry Division**
  http://www.acd.ucar.edu
- **National Oceanic and Atmospheric Administration**
  http://www.noaa.gov
- **National Weather Service**
  http://www.nws.noaa.gov
- **Student's Guide to Astrobiology**
  http://www.astrobiology.com/student.html
- **Tech-Interns.com**
  http://www.tech-interns.com/

Please take a moment to evaluate this product at:
http://ehb2.gsfc.nasa.gov/edcats/educational_topic

Your evaluation and suggestions are vital to continually improving NASA educational materials.
Thank you.



http://quest.nasa.gov/people/index.html

National Aeronautics and Space Administration

Educational Product	
Educators & Students	Grades 5-12

ET-2004-10-143-ARC

Educational Topic

Climatologist

Related Job Titles:

Climate Officer, Climate Forecaster, Climatology Researcher, Climatological Modeling Specialist, Atmospheric Scientist, Earth Systems Scientist

Job Description:

A Climatologist collects climate data, investigates climate indicators and makes predictions regarding climate patterns. This individual uses computer models to study how Earth's climate changes with time. They use glacial ice cores, lake sediments, tree rings, and other sources of information to determine the climate in Earth's past. They use sophisticated computer software programs that assist them in modeling the Earth's climate and check that data against known information. They conduct research to determine if humans are affecting Earth's present and future climate. Some Climatologists study climates on other planets in our solar system.

Interests / Abilities:

- Do you read and understand charts with special symbols easily?
- Can you perform calculations quickly with great accuracy?
- Do enjoy getting out a road map and figuring out what route to drive when preparing for vacation? Can you see more than one route to a destination?
- Are you curious about your surroundings and what processes shape them?
- Are you patient when it comes to completing forms requiring detailed information?

Suggested School Subjects / Courses:

- Math (algebra, trigonometry, calculus)
- Physics
- Meteorology
- Statistics
- Computer modeling
- Geography

Education / Training Needed:

The minimum education required for this position is a bachelor's degree in meteorology or atmospheric sciences from an accredited college or university. Experience in computer modeling techniques is extremely helpful for this job. To do research, at minimum a master's degree is required and a Ph.D. is highly desired for this position.

Areas of expertise:

- *Synoptic*: analyze data from satellites, radar, and surface-observing instruments
- *Weather forecasters*: prepare forecasts for public and specialized reports for aviation, marine and agriculture
- *Research*: study atmospheric physics, refine theories and improve mathematical/computer models of atmospheric processes and events

Additional Resources:

- **American Meteorological Society**
  http://www.ametsoc.org/AMS
- **Astrobiology Summer Academy**
  http://academy.arc.nasa.gov/
- **Education Pays Calculator**
  http://www.educationpays.org/calc.asp
- **Gradate Student Researchers Program**
  http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Graduate.Student.Researchers.Program.Brochure/.index.htmlt
- **MATHCOUNTS Competition**
  http://mathcounts.org/
- **Minority University Research and Education Programs**
  http://mured.nasaprs.com/
- **NASA Cooperative Education Program for college students**
  http://spacelink.nasa.gov/Educational.Services/NASA.Education.Programs/Student.Support/NASA.Cooperative.Education.Program/.index.html
- **NASA Jobs**
  http://nasajobs.nasa.gov/
- **NASA SHARP Internship Program for high-schoolers**
  http://www.mtsibase.com/sharp/
- **NASA Student Employment**
  http://nasajobs.nasa.gov/stud_opps/employment/index.htm
- **NASA Student Involvement Program student contests**
  http://www.nsip.net/index.cfm

What can I do right now?

- Set up your own weather station and provide your local radio station with a daily report.
- Get some work experience at the local airport, television or radio station as a weather data compiler or weather statistics researcher.
- Call the Automatic Terminal Information Service (ATIS) phone number and listen to the local airport's weather report.
- Learn to read and interpret the various types of weather maps, charts and data available through the Internet.
- Learn how to use database software.

- **National Oceanic and Atmospheric Administration**
  http://www.noaa.gov
- **National Severe Storms Laboratory**
  http://www.nssl.noaa.gov
- **National Weather Service**
  http://www.nws.noaa.gov
- **Schools with programs in meteorology**
  http://www.nssl.noaa.gov/edu/schools.html
- **Student's Guide to Astrobiology**
  http://www.astrobiology.com/student.html
- **Tech-Interns.com**
  http://www.tech-interns.com/

Please take a moment to evaluate this product at:
http://ehb2.gsfc.nasa.gov/edcats/educational_topic

Your evaluation and suggestions are vital to continually improving NASA educational materials.
Thank you.

National Aeronautics and Space Administration

Educational Product	
Educators & Students	Grades 5-12

ET-2004-10-118-ARC

Educational Topic

Meteorologist

Related Job Titles:

Weather Officer, Weather Forecaster, Meteorology Researcher, Meteorological Modeling Specialist, Atmospheric Scientist, Atmospheric Chemist

Job Description:

A Meteorologist collects weather data, surveys weather indicators and makes predictions regarding developing weather patterns. This individual advises air traffic control and other agencies about weather hazards such as thunderstorms, developing storm cells and fronts, turbulence, tornadoes, icing, flooding, flash flooding and other such weather-related phenomena. They issue to various governmental agencies and the public weather advisories for vehicles, aircraft and watercraft. They use sophisticated computer software programs that assist them in modeling the potential flow and intensity of storm cells and fronts. They are also available to participate in weather-related research projects that seek to provide more accurate forecasting methods over a longer time period.

Interests / Abilities:

- Do you read and understand charts with special symbols easily?
- Can you perform calculations quickly with great accuracy?
- Do enjoy getting out a road map and figuring out what route to drive when preparing for vacation? Can you see more than one route to a destination?
- Are you curious about your surroundings and what processes shape them?
- Are you patient when it comes to completing forms requiring detailed information?

Suggested School Subjects / Courses:

- Math (algebra, trigonometry, calculus)
- Physics
- Meteorology
- Statistics
- Computer modeling
- Geography

Education / Training Needed:

The minimum education required for this position is a bachelor's degree in Meteorology or Atmospheric Sciences from an accredited college or university. Experience in computer modeling techniques is extremely helpful for this job. To do research, at minimum a master's degree is required and a Ph.D. is highly desired for this position.

Areas of expertise:

- *Aeronautical:* study weather phenomena and its effects on flight (lightning, icing, etc.)
- *Synoptic:* analyze data from satellites, radar, and surface-observing instruments
- *Weather forecasters:* prepare forecasts for public and specialized reports for aviation, marine, and agriculture
- *Research:* study atmospheric physics, refine theories, and improve mathematical/computer models of atmospheric processes, and events
- *Climatologists:* collect, organize, archive, interpret, and publish climatological data.

Additional Resources:

- **American Meteorological Society**
  http://www.ametsoc.org/AMS
- **Astrobiology Summer Academy**
  http://academy.arc.nasa.gov/
- **Education Pays Calculator**
  http://www.educationpays.org/calc.asp
- **Gradate Student Researchers Program**
  http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Graduate.Student.Researchers.Program.Brochure/.index.htmlt
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- **National Oceanic and Atmospheric Administration**
  http://www.noaa.gov

What can I do right now?

- Set up your own weather station and provide your local radio station with a daily report.
- Get some work experience at the local airport, television, or radio station as a weather data compiler or weather statistics researcher.
- Interview pilots about how different weather phenomena affect their aircraft's flight characteristics.
- Call the Automatic Terminal Information Service (ATIS) phone number and listen to the local airport's weather report.
- Learn to read and interpret the various types of weather maps, charts, and data available through the Internet.
- Learn how to use database software.

- **National Severe Storms Laboratory**
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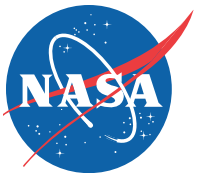

http://quest.nasa.gov/people/index.html